Environmental Technology Verification Program

Environmental and Sustainable Technology Evaluations

Test/QA Plan for Verification of Anaerobic Digester for Energy Production and Pollution Prevention

TEST/QA PLAN

for

Verification of Anaerobic Digester for Energy Production and Pollution Prevention

January 23, 2007

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January 23, 2007

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SECTION A

PROJECT MANAGEMENT

A4 VERIFICATION TEST ORGANIZATION

This verification test will be conducted under the auspices of the U.S. Environmental Protection Agency (EPA) through the Environmental and Sustainable Technology Evaluations (ESTE) and Environmental Technology Verification (ETV) programs. It will be performed by the awarded contractor (to be determined), under contract with the EPA.

The day to day operations of this verification test will be coordinated and supervised by contractor personnel, with the participation of the vendor, Wagner Anaerobics. This test will be conducted at Zimmerman Farm in Pitman, Schuylkill County, Pennsylvania, following the performance evaluation protocol developed by Dr. John H. Martin[(1)]. The field component of testing will be performed by contactor staff with assistance from the vendor and host site organizations. Vendor representatives will operate their respective technologies throughout the test unless they give written consent for the verification staff to carry out these activities. Quality assurance (QA) oversight will be provided by the contractor’s Quality Manager, and by the EPA Quality Manager at his discretion. The organization chart in Figure 1 is a suggested functional description of the responsibilities of the organizations and individuals associated with the verification test. Roles and responsibilities are defined further below.

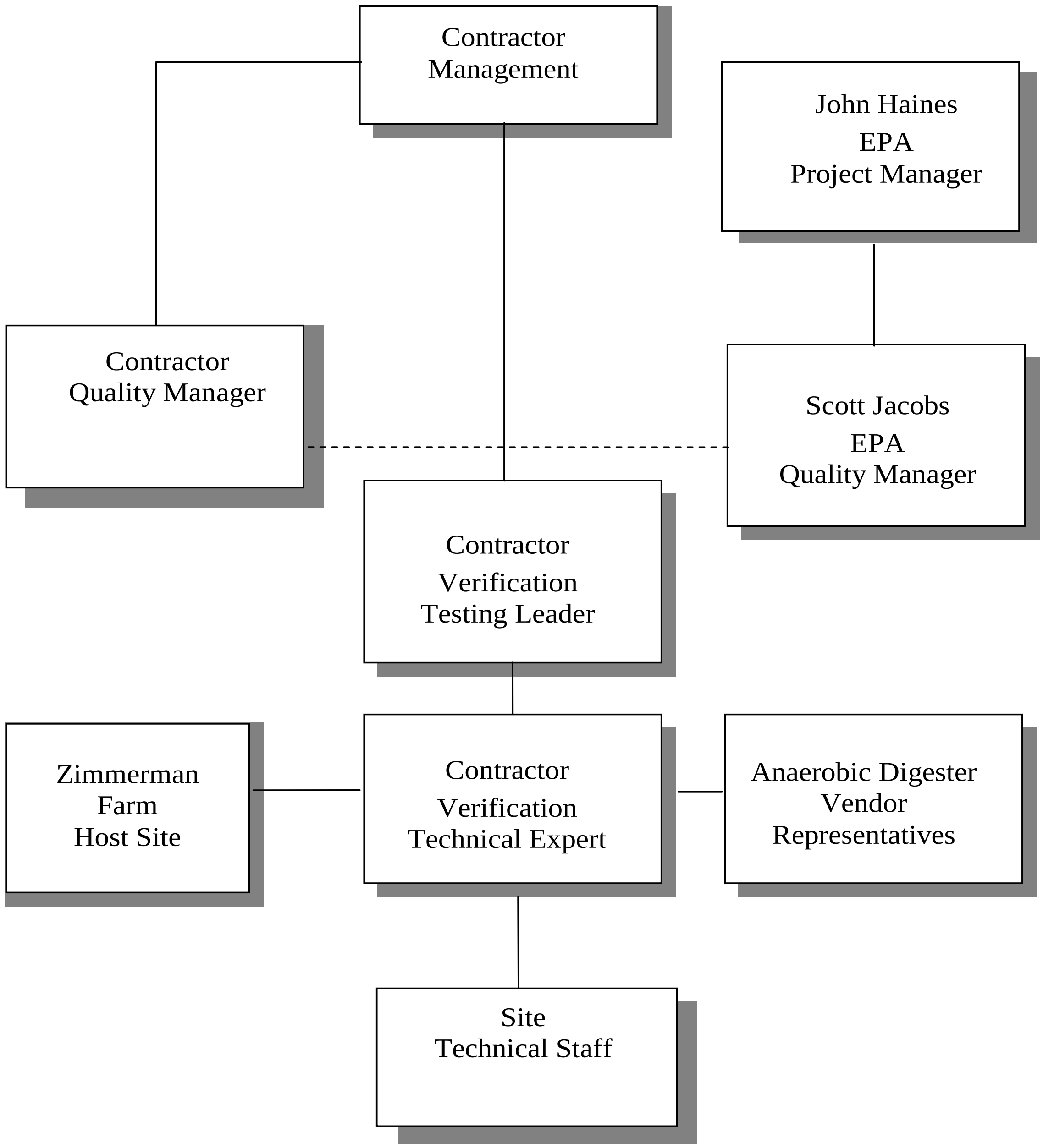


Figure 1. Organization Chart

A4.1 Contractor

Verification Testing Leader. This person will have overall responsibility for ensuring that the technical, schedule, and cost goals established for the verification test are met. Specifically, he will:

- Assemble a team of qualified technical staff to conduct the verification test.
- Direct the team (contractor, EPA, and host site staff) performing the verification test in accordance with the test/QA plan.
- Ensure that all quality procedures specified in the test/QA plan and in the ETV Quality Management Plan(2) (QMP) are followed.
- Prepare the draft and final test/QA plan, verification reports, and verification statements.
- Revise the draft test/QA plan, verification reports, and verification statements in response to reviewers' comments.
- Respond to any issues raised in assessment reports and audits, including instituting corrective action as necessary.
- Serve as the primary point of contact for vendor representatives.
- Coordinate distribution of the final test/QA plan, verification reports, and statements.
- Establish a budget for the verification test and manage staff to ensure the budget is not exceeded.
- Ensure that confidentiality of sensitive vendor information is maintained.
- Maintain communication with EPA's technical and quality managers.

Contractor Management. This individual will provide technical guidance and support for the verification testing program. Specifically, this person will:

- Support the testing leader in preparing the test/QA plan and organizing the testing.
- Review the draft and final test/QA plan.
- Review the draft and final verification reports and verification statements.
- Ensure that necessary contractor resources, including staff and facilities, are committed to the verification test. Ensure that confidentiality of sensitive vendor information is maintained.
- Support the testing leader in responding to any issues raised in assessment reports and audits.
- Facilitate a stop work order if the contractor or EPA QA staff discovers adverse findings that will compromise test results.

Contractor Technical Experts will work with the verification partners to conduct the testing of the anaerobic digester. Contractor staff will be on-site at the host site at various times throughout the verification test. The responsibilities of the technical staff will be to:

- Assist the host site in any and all aspects of performing the verification test as described in the test/QA plan.

Contractor Quality Manager. The contractor's Quality Manager will:

- Review the draft and final test/QA plan.
- Conduct a technical systems audit once during the verification test.
- Audit at least 10% of the verification data.
- Prepare and distribute an assessment report for each audit.
- Verify implementation of any necessary corrective action.
- Request that contractor management establish a stop work order if audits indicate that data quality is being compromised.
- Provide a summary of the QA/QC activities and results for the verification reports.
- Review the draft and final verification reports and verification statements.
- Assume overall responsibility for ensuring that the test/QA plan is followed.

A4.2 Vendors

The responsibilities of the vendor representatives are as follows:

- Review the draft test/QA plan.
- Approve the test/QA plan prior to test initiation.
- Provide their digester and associated operating equipment for evaluation during the verification test.
- Provide all other equipment/supplies/reagents/consumables needed to operate their monitors for the duration of the verification test.
- Operate the digester throughout the test, and provide written consent and instructions for contractor staff to carry out sample collection and data system download activities.
- Review the draft verification report and statement.

A4.3 EPA

EPA's responsibilities in the ETV and ESTE programs are based in part on the requirements stated in the "Environmental Technology Verification Program Quality Management Plan" (EPA QMP)[2]. The roles of the specific EPA staff are as follows:

EPA Quality Manager. The EPA's Quality Manager will:

- Review the draft test/QA plan.
- Perform at his/her one external technical systems audit during the verification test.
- Notify the contractor management of the need for a stop work order if the external audit indicates that data quality is being compromised.
- Prepare and distribute an assessment report summarizing results of the external audit.
- Review draft verification reports and statements.

Dr. John Haines is EPA's project manager for this ETV-ESTE test. Dr. Haines will:

- Review the draft test/QA plan.
- Approve the final test/QA plan.
- Review the draft verification reports and statements.
- Oversee the EPA review process for the verification reports and statements.
- Coordinate the submission of verification reports and statements for final EPA approval.

A5 BACKGROUND

The ETV-ESTE Program conducts third-party verification testing of commercially available technologies that improve the environmental conditions in the U.S. A stakeholder committee of buyers and users of such technologies guided the development of this test on anaerobic digesters.

Large scale animal agriculture in the United States produces manures in excess of one billion wet tons per year. This waste is commonly spread upon cropland both as a fertilizer and as a disposal mechanism. In many cases the available land is simply unable to absorb the quantities of nitrogen and phosphorus applied, leading to the potential for nutrient pollution of surface and groundwater. As a result of this activity, water quality and air quality are degraded throughout the nation. In fact, the three most common causes for listing waters as impaired are nutrients, sediments, and pathogens, all of which are heavily associated with manure land application at Concentrated Animal Feeding Operations (CAFOs). In fact, non-point source pollution from Animal Feeding Operations (AFOs) is listed as the leading cause of impairments in the nation's freshwater rivers and streams. Approximately half of the impaired rivers and streams in the U.S. are believed to be affected by animal feeding operations[3]. Development of commercial technologies that can treat the waste from such operations and recover value from it is highly desirable. In all cases, agricultural producers must do something with the manure produced by their operations and any process which reduces costs and/or generates a revenue stream is desirable.

Anaerobic digestion of livestock manures under controlled conditions to produce biogas (a mixture of methane and carbon dioxide) can provide livestock producers with the opportunity to increase net farm income, typically by using captured biogas to generate electricity for on-site use, or delivery to a local electric utility, or both. This biogas utilization approach also provides an opportunity to utilize waste heat captured from an engine-generator set to reduce on-farm demand for conventional fuels (e.g., fuel oil and propane) for water and space heating. Direct combustion of biogas for on-farm water and space heating in place of conventional fuels also is an option. An added benefit of anaerobic digestion of livestock manures is that potentially negative impacts of these wastes on air and water quality are reduced. This includes but is not limited to reducing the emissions of methane, a greenhouse gas with approximately 21 times the heat trapping capacity of carbon dioxide, when manure decomposes anaerobically under uncontrolled conditions. In addition, producing, capturing, and using manure biogas as a fuel reduces emissions of carbon dioxide from fossil fuel combustion to generate electricity or produce heat.

The steady development of biogas systems and an awareness of their merits has produced an increased level of interest by livestock producers in manure biogas production and broadened their use from mostly dairies to a variety of waste streams. Concurrently, a number of different system designs have emerged with claims about performance superiority as the number of system developers has increased. To facilitate comparison between systems and verify performance, a standard evaluation protocol[(1)] has been developed. This study is based on that protocol, sections of which have been excerpted as appropriate.

A6 VERIFICATION TEST DESCRIPTION AND SCHEDULE

This verification test will conduct a third-party performance evaluation of a commercially available anaerobic digester built at the Zimmerman Farm, a 600 acre farm near Pitman, PA. The farm has two livestock operations: a 1,000 head cattle-feeding operation and four poultry houses with a total of 120,000 chickens for the broiler market. The anaerobic digester has been designed by Wagner Anaerobics to utilize irregular mixtures of both waste streams, incorporating thermal pre-treatment of the mixed waste, mixed in a waste pit, to increase digestibility with chemical treatment and solids separation. This study will evaluate the performance of the digester for one year; starting after 5 HRTs (hydraulic retention times) are completed during the startup phase of the digester. The objective of the study is to verify digester performance in the areas of pathogen reduction, waste stabilization and biogas production. Due to the prototypical nature of the system, an economic analysis will not be conducted.

A6.1 Site and Facility Summary

The site for this study is Zimmerman Farm; a 600 acre farm located in Schuylkill County, near Pitman, Pennsylvania. The farm produces 120,000 chickens for the broiler market on a 7-week cycle, and has a 1,000 head cattle herd, growing out feeder calves for the beef market. The farm is currently not operating under a nutrient management plan.

The farm pastures young cattle, while older animals are fed in a slat-barn located next to the digester. Cattle are also fed in pens and a loafing shed located below the slat-barn. Manure from the pens and shed is scraped into a push-off pit where it is stirred and chopped by mixers, combined with yard runoff from a storage tank and then pumped to a mixing pit which also receives manure from the slat-barn. Poultry manure and occasionally swine manure from an associated operation is added to the mixing pit, whose contents are stirred and chopped before being pumped to the digester facility. Farm operations produce 6-8,000 gallons of manure slurry per day, with a solids content of 7-14%.

Initial start-up of the digester in May 2006 was affected by a monensin-type growth promoter used as an additive in the cattle feed, which inhibited methane production. The additive has been removed from the feed, and the digester was cleaned to remove inhibited contents. The digester facility will be re-started by January 2007.

The digester system was designed to allow the farm use of complex high-rate digestion systems by remotely linking operators and service technicians via a SCADA (Supervisory Control and Data Acquisition) system. The facility (see system schematics provided by Wagner Anaerobics in Appendix D) is a hybrid thermophilic system which uses 4 modular digester tanks (coated steel insulated to R25, 15,500 gal nominal volume) operated in series. The first three tanks are complete mix digesters with the final tank operated as a fixed-film digester. Each tank is provided with a 200 gpm mixing system and steam injection to maintain temperatures in the upper thermophilic region of 135-145° F (57-63°C). Other features of the system as given by Wagner Anaerobics are:

- High temperature/pressure (300°F/50 psi) pretreatment of manure to increase digestible fraction and reduce pathogens
- SCADA control system for remote monitoring of process activities and automatic dispatch of service personnel in case of system component malfunction
- Use of geo-fabrics for solids separation and low moisture solids for export
- Use of phosphorous stripping for removing soluble phosphorous from manure stream
- Use of hose reel irrigation system for reducing crop water stress
- Use of closed systems for elimination of odors from treatment process and storage lagoons
- Storage tanks only handle solids-free digested liquids
- All manure is handled by irrigation pipeline to reduce field compaction by heavy slurry tankers and tractors.

Manure slurry pumped from the mixing pit (T-3, see schematics in Appendix D) is processed by a Vogelsland grinder and pumped to a surge tank (T-4) which feeds a low-temperature heat exchanger (HE-1) connected to a 2,000 L pressurized cooker (HE-2). The contents are heated to 300°F at a pressure of 50 psi for 45 minutes, then routed to a series of heat exchangers (HE-9,-10) to recover excess heat before entering the first digester tank (D-1). Digested manure leaves the system at the last digester where it is pumped (while injecting polyelectrolytes and aluminum sulfate) into geo-fabric storage bags (AgBags, 30 cubic yards) designed to filter water from the treated solids. Solids are left in the bag to dry to 50% moisture, while the liquid, stripped of dissolved and suspended phosphorus, is pumped to a storage tank (T-7) for later field application. Solids are stored on-site. Figure 2 shows a photo of the heat exchanger and cooker.

Biogas is collected from each digester and AgBag and stored in tank T-9. Hydrogen sulfide (H_2S) is removed from the gas before combustion using a stripping tower (T-11) with potassium permanganate. The biogas is then compressed by a regenerative blower (BL-1) and burned in the boiler and generator sets (GenSet 1 and 2); any untreated excess gas is consumed by flare (F-17). The generators are equipped with both exhaust and water-jacket heat exchangers, with GenSet 1 providing 3-phase power for facility and farm use, while GenSet 2 provides single-phase power for sale thru net-metering.

The SCADA system provides remote process control while collecting data on system operation. Data collected includes:

- Temperature in each digester and process vessel
- Monitoring of parasitic loads by recording operating periods, volts and amperage of pumps and cooker
- Liquid levels and valve positions
- Influent and effluent flows are recorded and totalized using Rosemont Model 8600 magmeters
- Biogas flow is recorded and totalized as used and at each digester using orifice flow meters with Ashcroft differential pressure sensors.

Figure 2. Heat exchanger and cooker.

A6.2 Verification Schedule

The verification test of the anaerobic digester will be conducted over a period of approximately one year, beginning early 2007. Approximately every month a set of samples will be sent to the third party laboratory for analysis. Samples must be collected at regular, periodic intervals, so that a representative data set over an entire year can be obtained.

Within three months after the end of testing, a report will be drafted describing the evaluation and performance of the tested technology. The report will be subjected to peer reviews, and submitted to EPA for final signature. All documents will be submitted to EPA in electronic (Microsoft Word and Adobe portable document format [pdf]) and hard copy formats.

A7 QUALITY OBJECTIVES

This verification test will evaluate the performance of anaerobic digester technologies. This will include a comparison of the inflow and outflow composition of the digester material, as determined by standard laboratory reference methods. The quality of the reference measurements will be monitored by the inclusion of blank, duplicate, and performance evaluation (PE) audit samples. The PE audit samples will be analyzed using instruments or calibration standards that are independent of those used for the rest of the reference analyses. These samples are meant to independently confirm that the reference measurements are being performed correctly to produce accurate results. Control limits on the duplicate and PE samples are given in Section C1.

A8 SPECIAL TRAINING/CERTIFICATION

Documentation on training related to standard analytical chemistry methodology is to be maintained for applicable contractor, host site, or commercial laboratory technical staff in training files at the respective locations. The contractor Quality Manager will verify the presence of appropriate training records prior to the start of testing. If the vendors request that contractor or site staff operate and maintain their digesters during the verification test, the vendors will be required to train the those staff prior to the start of testing. The contractor will document this training with a consent form, signed by the vendor, which states which specific staff have been trained to operate their digester.

A9 DOCUMENTATION AND RECORDS

The records for this verification test will be contained in this test/QA plan, the protocols, chain of custody forms, laboratory record books (LRB), data collection forms, electronic files (both raw data and spreadsheets), and the final verification report. All of these records will be maintained in the Verification Testing Leader's office during the test and will be transferred to permanent storage by the contractor at the conclusion of the verification test. All contractor LRBs are to be stored indefinitely, either by the Verification Test Leader or contractor's management. EPA will be notified before disposal of any files. The results from the reference measurements made by the host site technical staff will be submitted to the contractor within five business days of making the measurement or obtaining the results of the analyses. Section B10 further details the data recording practices and responsibilities.

SECTION B

MEASUREMENT AND DATA ACQUISITION

B1 EXPERIMENTAL DESIGN SUMMARY

This verification test was designed to establish metrics for the Wagner digester that allow comparison to other systems and waste streams. Data will be generated from influent and effluent waste samples, gas production and utilization, and the anaerobic digester operating conditions over a one year period. Influent samples and effluent samples will be collected at a regular interval and analyzed for key parameters that show the performance of the digester. Table 1 lists the parameters to be determined, and the analytical methods, sampling frequency, sample type, number of samples per sampling event, and total number of sampling events for each parameter. Following the AgSTAR protocol(1) , biodegradibility of the raw and cooked manures will be measured with one sampling event at Month 3. Biogas composition measurements will be made on site and samples will be collected for laboratory analysis of methane and carbon dioxide. Finally, the digester operating temperature and hydraulic retention time (HRT) will be recorded monthly, based on measured effluent/influent flow rates.

The assumed cost for this test is $140,000. This funding will be spent on the test planning, sampling, sample analysis and shipping, quality assurance, audits, data analysis, report writing, and test coordination and logistics. A breakdown of these costs is shown in Table 2. This cost breakdown assumes an approximate sampling event cost of approximately $3.2K, for all influent, effluent and gas analyses. Therefore, 12 evenly spaced sampling events will be conducted at roughly one month intervals. Sampling events will be conducted by a contract staff member at the host site.

Table 1. Reference Analytical Methods

Parameter	Method	Sampling Frequency	Sample Type	Samples Analyzed Per Event	Total Sampling Events
Total Solids	EPA Method 160.3; Date issued: 02/01/1999	Monthly	Influent and effluent composites	4	13
TVS	EPA 160.4; Date issued: 02/01/1999(total volatile solids)	Monthly	Influent and effluent composites	4	13
TVA	STM(2005) 5560C (total volatile acids)	Monthly	Influent and effluent composites	4	13
Fixed Solids	Determined by difference b/n TS and TVS	Monthly	From AVG of TS and TVS results	4	13
COD	EPA Method 0410.4 (Colorimetric); Date issued: 08/01/1993	Monthly	Influent and effluent composites	4	13
NH_3-Nitrogen	EPA Method 0350.1 (Automated Colorimetry); Date issued: 1993	Quarterly	Influent, filtrate, and effluent composites	6	13
Total Kjeldahl Nitrogen	EPA Method 351.2 (Total Kjeldahl Nitrogen-1993)	Quarterly	Influent, filtrate, and effluent composites	6	13
Total Organic Nitrogen	Determined by difference b/n NH3-N and TKN	Quarterly	From AVG of TKN and NH3 results	6	13
Total Phosphorus	EPA Method 365.4	Quarterly	Influent, filtrate, and effluent composites	6	13
Dissolved Ortho Phosphate	EPA Method 365.3	Quarterly	Influent, filtrate, and effluent composites	6	13
Total coliforms	STM(2002) Multiple Tube 9221A-C 15 tube-MPN	Quarterly	Influent and effluent composites	2	5
Total strep.	STM(2002) Multiple Tube 9230A-B 15 tube MPN	Quarterly	Influent and effluent composites	2	5
Salmonella spp.	STM(2002) Multiple Tube 9260D MPN	Unknown	Influent and effluent composites	1	
M. avium paratuberculosis	NADC or Cornell methods (Stabel 1997)	Unknown	Influent and effluent composites	1	
pH	EPA Method 150.1	Monthly	Influent, filtrate and effluent composites	2-3	13
NPK Ratios plus Total Carbon	Penn State Ag. Lab Standard Manure Test 1	Quarterly	Solids Composite	1	5
Manure Biodegradability	Non-standard	Month 3	Raw and cooked manure	2	1
Gas Composition	CH4 and CO2 ASTM D1945;	Quarterly	From Gas Flow meter	3	5

Table 2. Approximate Costs Associated with Each Testing Task

Task	Cost (US$)
Test planning and setup	5K
Sampling	24K
Sample analysis and shipping/maintaining real time measurement records	56K*
Quality assurance	5K
Audits	5K
Data reduction and analysis	15K
Report writing	15K
Test coordination and logistics	15K
Total	**140K**

*

The following sections describe the evaluations that will be conducted for each of the digester performance parameters.

B1.1 Waste Stabilization

Using the measured mass flow of the influent and effluent streams along with the measured concentrations of the Table 1 parameters, digester performance will be determined by calculating a material balance for the system waste streams. Following guidelines given in Section B2, composite samples of the influent (at T-4, see Appendix D) and effluent (at D-4) will be collected monthly and analyzed for Total Solids (TS), Total Volatile Acids (TVA), Total Volatile Solids (TVS), Chemical Oxygen Demand (COD), Fixed Solids (FS) and pH. Every quarter month those samples will also be analyzed for Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Ammonia Nitrogen (NH_3-N) and Organic Nitrogen (ON). The degree of waste stabilization will be reported as differences between the influent and effluent of these measured parameters. AGBAG performance will be measured monthly by composite sampling fresh filtrate (at VA-10 in Appendix D) and analyzing for Orthophosphate (OP), TP, and NH_3-N. TS, TVS, COD, FS and pH will be measured quarterly. Dried solids will also be analyzed quarterly by composite for NPK ratio (ratio of nitrogen, phosphorus and potassium). Prior to beginning the study, a complete suite of samples and parameters will be analyzed as a performance evaluation of the selected reference laboratory, using actual digester samples as the spike matrix.

B1.2 Biodegradability

Given the farm's manure mix, and since reduction of manure refractory fraction is an integral part of this system, composites of raw manure (at T-4) and cooked manure (at P-2) will be sampled at month 3. Samples will be used in long-term bench tests as outlined in the AgSTAR protocol(1). Tests will be conducted at temperatures approximating the digester average temperature and analyzed for TVS concentration at Days 15, 30, 45 and 60. Complete details of this test method will be provided by consultation with AgSTAR representatives.

B1.3 Pathogen Reduction by Inference

The potential pathogen reduction of the system will be measured by quarterly sampling of the influent (T-4) and effluent (D-4) for enteric bacteria. Total coliforms and fecal streptococcus will be used as indicators of pathogen reduction, quantified as per Table 1. Assays for *M. avium paratuberculosis and Salmonella spp* will be conducted as resources allow. Reductions in density of pathogen indicator organisms will be reported in colony-forming units (CFU) per 100ml.

B1.4 Hydraulic Retention Time and Temperatures

Using influent/effluent flow data collected by the SCADA system, actual digester HRT will be calculated monthly. Flow meters are new and have been factory calibrated, and cannot be recalibrated during the study period. Vendor will check flow meter operation by recording pump intervals with the SCADA system. Average temperatures for ambient air, digesters and influent/effluent will be determined monthly using the SCADA system. The system uses Rosemont RTD thermocouples whose accuracy will be checked monthly by the vendor using a NIST-traceable dial thermometer (VWR's 37000-426 is suitable)

B1.5 Biogas Production

Total biogas production will be determined in this study using the vendor's orifice-type meters linked to Rosemont Differential Pressure Sensors (Model 8600) located on each digester and the main biogas supply line. Due to cost restrictions, the vendor's gas flow meters will not be calibrated. As a check on meter performance, biogas production will be estimated by utilization parameters prior to beginning the study. A calibrated gas flow meter will be provided to the vendor, who will install it on the outlet side of the compressor (BL-1). Monthly gas production and study total will be reported under standard conditions (0° C and 1 atm) as per the AgSTAR protocol[(1)].

B1.6 Biogas Composition

Biogas composition will be monitored monthly by the contractor using detector tubes (Draeger or Gastec) for CO_2 and H_2S. Measurements will be conducted before the biogas enters the stripping tower (T-11). At least three replicate measurements will be made for each event,

Laboratory analysis of biogas composition by volume following ASTM 1945 will be conducted quarterly for methane, CO_2 and Nitrogen. Duplicate samples will be collected at the outlet of the stripping tower (T-11) in Tedlar bags or Summa canisters and shipped for analysis. Ammonia and H_2S will be measured by detector tube during these events, collecting three replicate samples at the outlet of the tower (T-11). In addition, quarterly measurements of water vapor will be made using detector tubes (Draeger or Gastec).

B1.7 Biogas Utilization

In this system, totalized biogas flow is collected at the main biogas supply line before distribution to the boiler or GenSets. The SCADA system will be used by the vendor to determine kW hours of electricity produced and boiler operation parameters. Beneficial use of GenSet heat and exhaust will be measured by Btu meter or estimated from SCADA data by the vendor contractor. GenSet operating hours will be recorded monthly from their respective instrument panels by the contractor. Thermal conversion efficiency, on-line efficiency, average GenSet output and average capacity utilization efficiency will be calculated by the contractor monthly and on an annual basis when the study is completed, using the formulas given in the AgSTAR protocol[(1)] equations 1a and 1b.

B1.8 Reporting

Since the Wagner Anaerobics system in this test processes mixed manure from cows and chickens, results for biogas production (under standard conditions) and electricity generated will be reported as a function of the average daily loading of TVS and COD over the 12-month evaluation period. Digester material balances will be reported in table format using a mg/liter basis (except for pH), averaging influent and effluent parameters for the study period to determine treatment efficiency, following the formulas given in Appendix A of the AgSTAR protocol.(1) Reductions in density of pathogen indicator organisms will be reported in colony-forming units (CFU) per 100 ml. For the parameters tested, a comparison between whole effluent and separated liquid on a mass per liter basis will be made. Following the Agstar protocol(1) and the examples given in the Gordondale evaluation,(3) greenhouse gas reductions based on biogas production and utilization combined with reduced demand for electricity generated by fossil fuels will be estimated. Table 3 lists the performance parameters and the measurements used to calculate each.

Following procedures cited in the AgSTAR protocol, (1) reductions must be shown to be statistically significant to at least the $P<0.05$ level, and confidence interval estimates must be reported. Suspected outlier data shall be tested at $P<0.05$ using Dixon's method, as cited in the protocol.(1)

In addition, the data sheets found in Appendix B are to be filled out in full, as these forms help produce estimates related to operation and maintenance costs. These data sheets record important operational and logistical data that help characterize the operation of the anaerobic digester system being tested.

Table 3. Critical Measurements Used to Calculate Each Performance Parameter.

Performance Parameter	Measurement Used in Calculation	
Waste stabilization	TS, TVA, TVS, COD, FS, pH, TKN, TP, NH_3-N, ON	Influent concentration minus effluent concentration
Solids separation	OP, TP, NH_3-N, TS, TVS, COD, FS, pH	Whole effluent concentration minus separated liquids concentration
Dried solids	NPK	Mass fraction of N, P, K in dried solids
Biodegradability	TVS	Raw influent TVS concentration minus Final TVS concentration
Pathogen reduction by inference	Total coliforms, fecal streptococcus	Influent minus effluent (colony forming units per 100 mL)
Hydraulic retention time and temperature	Time from SCADA and temp	System HRT: System volume/influent volume; Actual monthly influent/effluent
Biogas production	Flow rates from SCADA, elapsed time	Totalizer volume/day
Biogas composition	CO, H_2S, CO_2, N_2, methane	Component volume/Total gas volume*100
Biogas utilization	kWh of electricity generated, Btu of exhaust or genset heat	Watts of electricity + Converted BTUs

B2 SAMPLE COLLECTION

As described above (Section A6), samples for the evaluation of digester performance will be collected throughout the verification test and submitted to a third-party laboratory for analysis. The samples will be collected following guidelines set in each standard reference method listed in Table 1 and summarized in Section B4. The methods describe the appropriate sampling containers, preservation techniques, and maximum holding times. This study will follow the AgSTAR protocol, (1) using only ice or refrigeration to preserve samples. Aliquots of influent and effluent will be transferred to appropriate sample containers, preserved as necessary, and submitted to the independent laboratory for analysis. A sufficient amount of sample will be collected to split as needed for nutrient, microorganism, and solids analysis. Given the inherent variability in animal manures, care will be taken to ensure that all influent and effluent samples collected for analysis are representative of the average daily flow. While the most desirable approach would be to collect 24-hour flow composite samples, it is recognized that this approach generally is impractical for collection of livestock manure samples. Samples will be collected from the sites given above in the Sections 1.1 to 1.3. Composites will be collected from piping sample ports, using a series of at least six grab samples collected over a period of no less than one hour and combined into a single composite sample. During the compositing process, grab samples will be kept iced to enhance preservation. Composite samples shall be no less than 20 L (~5 gal) and sub samples withdrawn for analysis shall be no less than one L (~ one qt). Where replicate samples are being analyzed, two sub samples will be withdrawn and sent to the laboratory. If the coefficient of variation for influent or effluent total solid concentrations exceeds 25 percent, more frequent sample collection and analysis may be necessary.

B3 SAMPLE HANDLING AND CUSTODY REQUIREMENTS

Sample custody will be documented throughout collection, transport, shipping (if necessary), and analysis of the samples, using standard forms used by the independent laboratory for this purpose. Each chain-of-custody (COC) form summarizes the samples collected and analyses requested. The COC form will track sample release from the sampling location to the independent laboratory. Each COC form will be signed by an authorized person once that person has verified that the COC form is accurate. The original COC forms will accompany the samples and the shipper will keep a copy. Upon receipt at the laboratory, COC forms will be signed by the person receiving the samples once that person has verified that all samples identified on the COC forms are present. Any discrepancies will be noted on the form, and the sample receiver will immediately contact the Verification Test Coordinator to report missing, broken, or compromised samples. Copies of all COC forms will be delivered to the Verification Test Coordinator, and maintained with the test records.

All anaerobic digester influent and effluent samples shall be immediately iced or refrigerated following collection and delivered within 24 hours of collection for analysis. Sub-samples shall not be acidified for preservation.

B4 LABORATORY REFERENCE METHODS

Only analytical methods described in Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 (U.S. Environmental Protection Agency, 1983)[3] or Standard Methods for the Examination of Water and Wastewater, 21st edition (American Public Health Association, 2005)[4] are acceptable unless it can be demonstrated that an alternative provides the same degree of precision and accuracy. All analyses of influent and effluent samples shall be performed by an analytical laboratory with certification to perform analyses of wastewater to satisfy National Pollutant Discharge Elimination System (NPDES) reporting requirements or have comparable certification. In the event that an analytical laboratory without the appropriate certification (such as university research laboratory) is used, that laboratory must have an ongoing quality assurance/quality control program that is comparable to such programs required for certification. The laboratory used must have previous demonstrable experience in analyzing samples with high solids concentrations, and duplicate analyses of individual samples shall be performed for all parameters.

Table 1 of Section B1 lists the reference analytical methods that will be used for the sample collection and reference analyses during this verification process. The collection of the samples will be the responsibility of the contractor which may assign responsibility to either the independent laboratory staff, or contractor staff. Results of the sample analyses will be provided to the contractor within 14 days of sample receipt. The contractor will provide the EPA project manager with all sample results within one week of receipt of the sample results from the laboratory. All the standard analytical methods listed in Table 1 are attached in Appendix A.

B4.6 Data Collection

All meters used to measure biogas production and utilization, electricity generated, engine-generator set hours, and waste heat beneficially utilized shall be calibrated or recalibrated, if previously used, by the manufacturer prior to the beginning of each performance evaluation. In addition, each meter shall have a manually non-resetable totalizer to avoid accidental data loss and all meter readings shall be recorded at least during every sampling episode with the date and time of the meter reading noted. In addition, a copy of the digester operator records shall be obtained monthly.

B5 QUALITY CONTROL AUDITS AND REQUIREMENTS

As described in Section B2, a third-party laboratory will follow their standard QA/QC protocols for analysis of quality control samples with each set of samples analyzed. Analysis of quality control samples may include initial calibration verifications, initial calibration blanks, method blanks, lab control standards, matrix spikes, matrix spike duplicates, continuing calibration verifications, and continuing calibration blanks, as required by the referenced methods. Results of all quality control samples will be included in the verification test documentation, and must fall within the laboratory's quality requirements. The quality of the reference measurements will also be monitored by including performance evaluation audit samples submitted as blind (i.e., unknown) samples to the third-party laboratory. The performance evaluation audit samples will be prepared from certified standards that are independent of those used for reference method calibration, and will include prepared standards and/or matrix spikes. These samples will be used to independently confirm that the reference measurements are being performed correctly and are producing accurate results. The contractor's Quality Manager will perform a technical systems audit at least once during this verification test that may include visits to both the test site and the third-party analytical laboratory, and will audit at least 10% of the verification data obtained in this verification test. The EPA Quality Manager will also conduct an independent technical system audit at his/her scheduling discretion.

Steps will be taken to maintain the quality of the data collected during this verification test. Quality control samples producing results which do not meet the laboratory's standard requirements will be reanalyzed. If the results are still outside the required tolerance, the reference instrument will be recalibrated and the samples will be reanalyzed. If the outlying results persist, the affected data will be marked and the affected parts of the verification test may be repeated. Sample results which do not meet these requirements will also be marked, and excluded from comparison to the results obtained from other operating sites.

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

The equipment used for all the analyses will be tested, inspected, and maintained as per the standard operating procedures of the third-party analytical laboratory or the standard methods being used to make each measurement. The reference analyses listed in Section B4 require use of the following apparatuses and instrumentation: reflux apparatus, drying oven, spectrophotometer, stereoscopic microscope, ultraviolet unit for sanitization, autoclave or steam sterilizer, incubator, pH meter, vortex mixer, gas chromatograph, thermal conductivity detector, continuous-flow analysis equipment, colorimetric detector. These activities (i.e., inspection, maintenance, and test of the instruments) will be done as directed by the third-party laboratory.

B7 INSTRUMENT CALIBRATION AND FREQUENCY

The instruments used by the third party laboratory for sample analyses (e.g., spectrophotometer, gas chromatograph, thermal conductivity detector, colorimetric detector, continuous-flow analysis equipment, and pH meter) will be calibrated per the standard reference methods being used to make each measurement or the standard operating procedures of the reference laboratory. In the event that recalibration is necessary due to maintenance activities performed on the analyzer or any malfunction, recalibration will be carried out by the commercial laboratory or by the instrument vendor. All calibration records will be documented by the commercial laboratory dedicated to the individual instruments.

B8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

All materials, supplies, and consumables will be ordered by the Verification Test Coordinator or designee. The contractor will also rely on previous experience or recommendations from EPA advisors, stakeholders, commercial laboratory, or instrument vendors. When possible, NIST traceable standards will be used.

B9 NON-DIRECT MEASUREMENTS

Data published previously in the scientific literature or other source will not be used during this verification test.

B10 DATA MANAGEMENT

Various sample analysis data will be acquired and recorded electronically or manually by the commercial laboratory during this verification test. All maintenance activities, repairs, and operator observations relevant to the operation of anaerobic digesters will also be documented by the operator, contractor or host site personnel on data sheets. Results from the analytical methods, including raw data, analyses, and final results, will be compiled by the contractor, preferably in electronic format, and submitted to the EPA project manager at the completion of sample analyses.

Records generated by the third-party laboratory during the verification test will be reviewed by the contractor within two weeks of receipt before the records are used to calculate, evaluate, or report verification results. If a contractor staff member generated the record, this review will be performed by another contractor technical staff member involved in the verification test, but not the staff member who originally generated the record. The review will be documented by the person who will perform the review by adding his/her initials and date to the hard copy of the record being reviewed. In addition, any calculations performed by the third-party laboratory will be spot-checked by contractor technical staff to ensure that calculations are performed correctly. Calculations to be checked include any statistical and deterministic calculations described in the analytical methods listed in this test/QA plan. The contractor QA staff will conduct an audit of data quality. This audit will consist of a review of at least 10% of the test data by the contractor and/or EPA Quality Manager. During the course of any such audit, the contractor Quality Manager will inform the technical staff of any findings and any need for immediate corrective action. If serious data quality problems exist, the contractor Quality Manager will request that the contractor project management issue a stop-work order. Once the assessment report has been prepared, the Verification Test Coordinator will ensure that a response is provided for each adverse finding or potential problem, and will implement any necessary follow-up corrective action. The Quality Manager will ensure that follow-up corrective action has been taken. Table 4 summarizes the data recording process.

Table 4. Summary of Data Recording Process

Data to Be Recorded	Where Recorded	How Often Recorded	By Whom	Disposition of Data
Dates, times, and details of test events	Data sheets and testing notebook	Start/end of test, and at each change of a test parameter	EPA, contractor, and Vendor	Used to organize/check test results; manually incorporated in data spreadsheets as necessary
Calibration information	Data sheets and testing notebook	Prior to sample preparation	EPA, contractor, and Vendor	Manually incorporated in data spreadsheets as necessary
Digester parameters	Recorded electronically.	Recorded continuously.	EPA, contractor, and Vendor	Comma delimited text files.
Reference method procedures	Laboratory record books, or data recording forms	Throughout sample analysis process	EPA, contractor, and Vendor, and Reference Lab	Transferred to spreadsheets or laboratory record book

SECTION C

ASSESSMENT AND OVERSIGHT

C1 ASSESSMENTS AND RESPONSE ACTIONS

Every effort will be made in this verification test to anticipate and resolve potential problems before the quality of performance evaluations is compromised. The main objective of these assessments is to determine whether the test/QA project plan is being implemented as originally approved. Internal quality control measures described in this test/QA plan, which is peer reviewed by a stakeholder group (panel of outside experts), implemented by the technical staff and monitored by the Verification Testing Leader, will give information on data quality on a regular basis. The Verification Testing Leader is responsible for interpreting the results of these checks and resolving any potential problems. Technical staff has the responsibility to identify problems that could affect data quality or the ability to use the data. Any problems which are identified will be reported to the Verification Testing Leader, who will work to resolve any issues. Action will be taken to control the problem, identify a solution to the problem, and minimize losses and correct data, where possible. Independent of any EPA QA activities, the contractor will be responsible for ensuring that the following audits are conducted as part of this verification test.

C1.1 Performance Evaluation Audits

A Performance Evaluation audit will be conducted by the contractor’s technical staff to assess the quality of the reference method measurements made in this verification test. The performance evaluation audit of the reference methods listed in Table 1 of Section B1 will be performed by supplying each reference method with a blind, independent, NIST-traceable standard provided by the contractor. The performance evaluation audit samples will be analyzed in the same manner as for all other samples, and the analytical results for the performance evaluation audit samples will be compared to the nominal concentration. The target criterion for this performance evaluation audit is agreement of the analytical result within 25% of the nominal concentration. If the performance evaluation audit results do not meet the tolerances shown, they will be repeated. If the outlying results persist, a change in reference instruments and a repeat of the performance evaluation audit may be considered. This audit will be performed once prior to the start of the test and once during the verification test, and will be the responsibility of the Verification Testing Leader or his/her designee.

C1.2 Technical Systems Audits

The contractor or his/her designee will perform a technical systems audit once during this verification test. The purpose of this audit is to ensure that the verification test is being performed in accordance with this test/QA plan and any Standard Operating Procedures (SOPs) used by the third-party laboratory. The contractor's Quality Manager, or a designee, may review the reference analytical methods and/or SOPs used, compare actual test procedures to those specified or referenced in this test/QA plan, and review data acquisition and handling procedures. In the technical systems audits, the contractor's Quality Manager will tour the test site, observe sampling and sample recovery, inspect documentation of sample chain-of-custody, and review instrument-specific record books. He may also visit the third party laboratory where all of the reference method analyses are conducted, to review procedures and adherence to this plan and applicable SOPs. A technical systems audit report will be prepared, including a statement of findings and the actions taken to address any adverse findings. The EPA Quality Manager will receive a copy of the contractor's technical systems audit report. EPA QA staff will also conduct an independent on-site technical systems audit during the verification test. The findings will be communicated to technical staff at the time of the audit and documented in a technical systems audits report.

C1.3 Data Quality Audits

The contractor Quality Manager will audit at least 10% of the verification data acquired in the verification test. The contractor Quality Manager will trace the data from initial acquisition, through reduction and statistical comparisons, to final reporting. All calculations performed on the data undergoing the audit will be checked.

C1.4 QA/QC Reporting

Each assessment and audit will be documented in accordance with Section 3.3.4 of the ETV AMS Center QMP(2). The results of the technical systems audit will be submitted to EPA. Assessment reports will include the following:

- Identification of any adverse findings or potential problems
- Response to adverse findings or potential problems
- Recommendations for resolving problems
- Confirmation that solutions have been implemented and are effective
- Citation of any noteworthy practices that may be of use to others.

C2 REPORTS TO MANAGEMENT

The contractor Quality Manager, during the course of any assessment or audit, will identify to the technical staff performing experimental activities any immediate corrective action that should be taken. If serious quality problems exist, the contractor Quality Manager is authorized to request a stop work order from the contractor's management. Once the assessment report has been prepared, the Verification Testing Leader will ensure that a response is provided for each adverse finding or potential problem and will implement any necessary follow-up corrective action. The contractor Quality Manager will ensure that follow-up corrective action has been taken. The test/QA plan, final report, and verification statement are reviewed by EPA quality assurance staff and the contractor management staff. Upon final review and approval, all documents will be posted on the ETV website (www.epa.gov/etv).

SECTION D

DATA VALIDATION AND USABILITY

D1 DATA REVIEW, VALIDATION, AND VERIFICATION REQUIREMENTS

The key data review requirements for the verification test are the collection of QC samples as outlined in the test/QA plan, a comparison of field data sheet comments against final data to flag any suspect data, and a review of final data to resolve any questions about apparent outliers. The QA audits, as described within this document are designed to assure the quality of this data.

D2 VALIDATION AND VERIFICATION METHODS

Section C1, the Assessment and Response section, provides a thorough description of the validation safeguards employed for this verification test.

D3 RECONCILIATION WITH USER REQUIREMENTS

The data will be compiled into an ETV verification report and verification statement. These reports will be submitted to EPA in Microsoft Word and Adobe pdf format and subsequently posted on the ETV website.

SECTION E

REFERENCES

1. Martin, J. H. “A Protocol for Quantifying and Reporting the Performance of Anaerobic Digestion Systems for Livestock Manures”. Interim Final September 2006; Association of State Energy Research and Technology Transfer Institutions, U.S. EPA AgSTAR Program, U.S. Dept. of Agricultural Rural Development. http://www.epa.gov/agstar/pdf/assessing_digester_perform_protocol.pdf

2. U.S. EPA. December 2002 “Environmental Technology Verification Program Quality Management Plan", EPA/600/R 03/021.

3. Water Quality Report, 2000 available at http://www.epa.gov/305b/2000report/chp2.pdf

4. Standard Methods for the Examination of Water and Wastewater, 21th ed.; Clesceri, L. S.; Greenberg, A. E.; Eaton, A. D., Eds.; American Public Health Association, American Water Works Association, Water Environmental Federation: Washington, DC, 1998; pp 5-535-55.

5. U.S. EPA. 1983 Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 U.S. Environmental Protection Agency.

6. Stabel, J.R. 1977. “An Improved Method for the Cultivation of Mycobacterium paratuberculosis from Bovine Fecal Samples and Comparison with Three Other Methods”. J. Veterinary Diagnostics Investigations, 9:375-380.

7. ASTM Methods, 2006. American Society for Testing and Materials International, West Conshohocken, PA.

8. Martin, J. H. July 2005. “An Evaluation of a Mesophilic, Modified Plug Flow Anaerobic Digest for Dairy Cattle Manure” For U.S. EPA Contract No. GS 10F-0036K..

APPENDIX A

REFERENCE ANALYTICAL METHODS

A.1 EPA Method 160.4 TVS
A.2 EPA Method 0410.4 COD(Colorimetric)
A.3 EPA Method 0350.1 NH3-N(Automated colorimetry)
A.4 EPA Method 0350.2 NH3-N(Titration)
A.5 Penn State Agricultural Analysis Lab: Standard Manure Test 1
A.6 EPA Method 0351.1 (Kjeldahl, Colorimetric/auto)
A.7 EPA Method 0351.2 (Kjeldahl, Colorimetric)
A.8 EPA Method 0351.3 (Kjeldahl, Colorimetric/Titrimetric)
A.9 EPA Method 0351.4 (Kjeldahl, Potentiometric)
A.10 EPA Method 365.3 Dissolved Orthophosphate
A.11 EPA Method 365.4 Total Phosphorus
A.12 SM9260 D (2) Salmonella spp.
A.13 SM2540 (2) Volatile and Fixed solids
A.14 EPA Method 150.1 pH
A.15 EPA Method 160.3 Total Solids
A.16 EPA Method 3C Biogas composition
A.17 SM9221 A-C (2) Total coliforms
A.18 SM5560 C (2) TVAA.19 ASTM D1954 (5) Biogas composition
A.20 SM9230 A-B (2) Fecal Streptococcus
A.21 Penn State Ag. Lab Standard Manure Test 1

APPENDIX B

Verification Data Sheets

General Information	
1. Name of operation	Zimmerman Farm
2. Address (including county)	Pittman, PA
3. Type of operation	Mixed; waste streams from cattle and broilers
4. Numbers and ages of livestock	
5. Type of collection system	

Notes:

Biogas Production	
1. Type of digester (e.g. mixed, plug-flow, attached film, or covered lagoon)	Fully mixed with final stage attached film; thermophilic
2. Name of system designer, address, and other contact information	
3. Digester design assumptions	
a. Number and type of animals	
b. For lactating cows, average body weight or average milk production	
c. Bedding type and estimated annual quantity used	
d. Manure volume, ft3/day	
e. Wastewater volume, ft3/day (e.g. none, milking center wastewater, confinement facility wash-down, etc.)	
f. Other waste volume(s), ft3/day (e.g. none, food processing wastes, etc.) with physical and chemical characteristics (e.g. concentrations of total solids, total volatile solids, chemical oxygen demand, etc.)	
4. Physical description	
a. General description including types of construction materials (e.g. partially below grade, concrete channel plug-flow with flexible cover, etc.)	
b. Dimensions (length and width or diameter and height or depth)	
c. Type(s), location(s), and thickness(s) of insulation	
d. Operating volume and ancillary biogas storage volume if present	
e. Design hydraulic retention time	
5. Monthly summaries of operational details	
a. Number and type of animals	
b. Other waste volume(s) and physical and chemical characteristics	
c. Frequency of waste addition (e.g. once per day, twice per day, etc.)	

Biogas Production (continued)	
d. Pretreatment of digester influent (e.g. none, solids separation by gravitational settling, screening, etc. with details)	
e. Average daily digester temperature and monthly range	
f. Treatment of digester effluent (e.g. none, solids separation by screening, etc. with details)	
g. Method of digester effluent storage (e.g. none, earthen pond, etc.)	
h. Use of monensin or any other antibacterial growth promoters that could affect biogas production	Farm had been using Rumensin by Eli Lilly

Biogas Utilization	
1. Biogas utilization (e.g. none, generation of electricity, use on-site as a boiler or furnace fuel, or sale to a third party)	
a. Type of engine-generator set (e.g. internal combustion engine, micro turbine or fuel cell with the name of the manufacturer, model, and power output rating (kW) for biogas	ICE Waukesha Model 817
b. Pretreatment of biogas (e.g. none, condensate trap, dryer, hydrogen sulfide removal, etc. with the names of manufacturers, models, etc.)	
c. Exhaust gas emission control (e.g. none, catalytic converter, etc.)	
d. If interconnected with a utility	
i. Name of the utility	
ii. Type of utility contract (e.g. sell all/buy all, surplus sale, or net metering)	
e. If engine-generator set waste heat utilization	
i. Heat source (e.g. cooling system or exhaust gas or both)	
ii. Waste heat utilization (e.g. digester heating, water heating, space heating, etc.)	
3. f use on-site as a boiler or furnace fuel, a description of the boiler or furnace including manufacturer, model, and rated capacity	
4. If biogas sale to a third party, a description of the methods of processing, transport, and end use	

Cost Information	
1. "As built" cost of total system	
2. Cost basis (e.g. turnkey by a developer, owner acted as the general contractor, constructed with farm labor, etc.)	
3. An itemized list component costs (e.g. the digester, the biogas utilization system, etc.)	

APPENDIX C

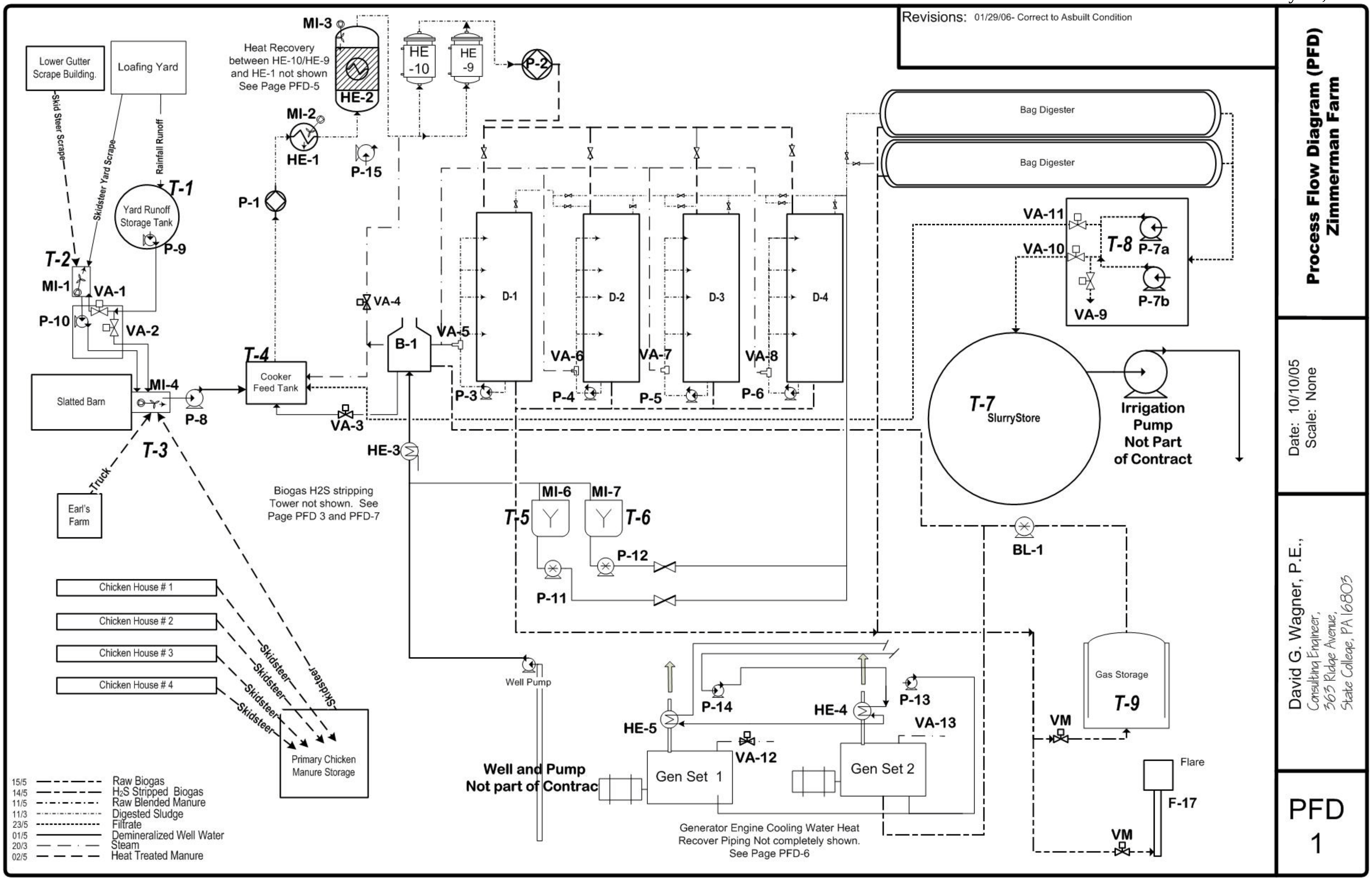
Data Checklist

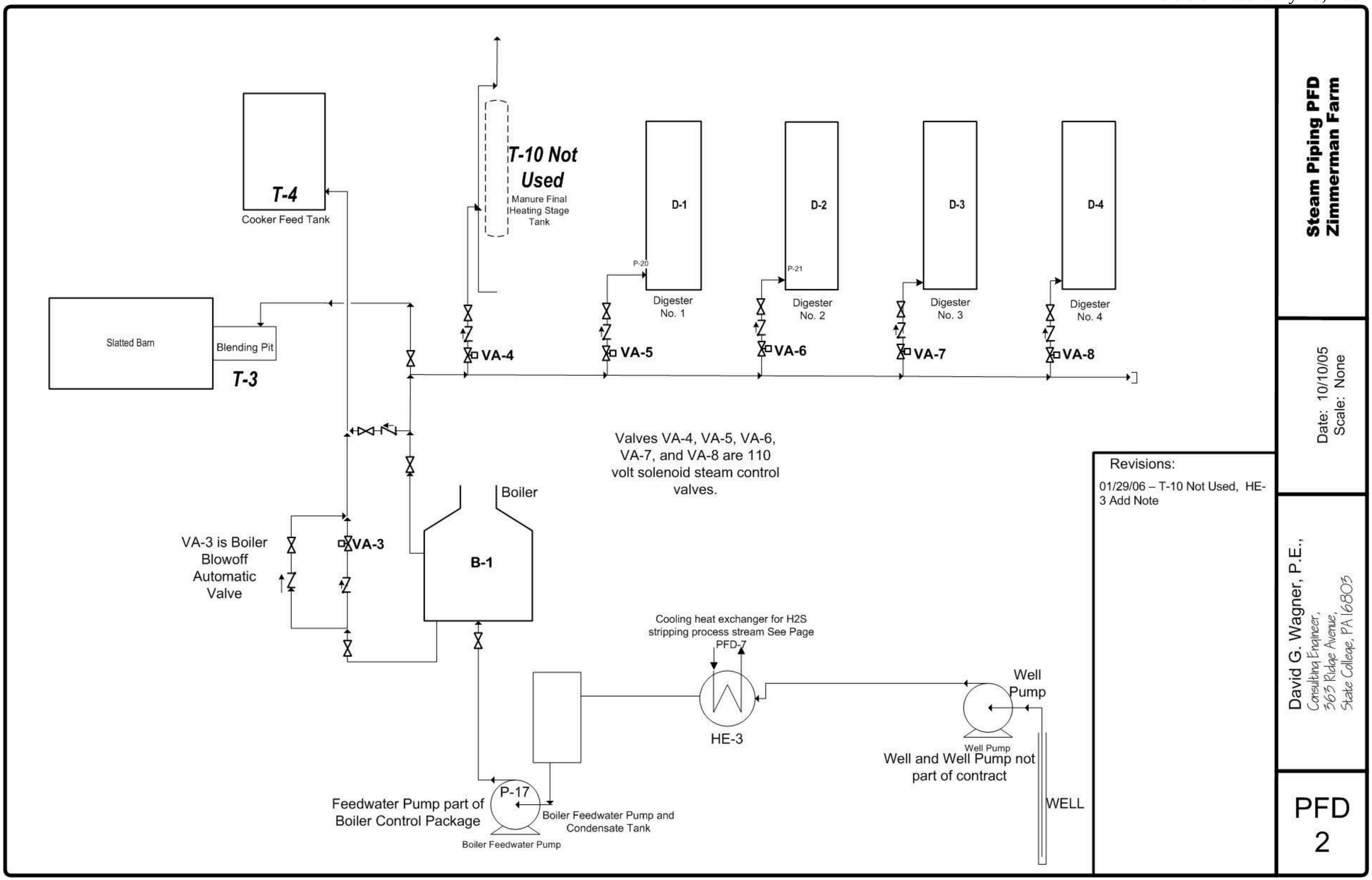
Parameter	Method	Sampling Period	Sample type	Total Data Points/event	Method LOD (mg/L)	Notes
Biogas Utilization Factors	Calculate Thermal Conversion Efficiency, On-line Eff., Average output Eff., Average Capacity Utilization Eff.	Monthly			Month and study averages	Calculated by contractor
Operational Information	Complete farm and facility characterization (Appendix B)	Throughout Study			During initial phase of study	Completed by contractor with farmer and vendor
Digester Records	Copy of digester operational records kept by vendor	Daily			Monthly	Data collected by vendor stored monthly by contractor
Performance Evaluations (PE)	Inclusion of blind spiked samples into lab samples	Pre-study and during	Waste Stabilization samples	To be determined	2 events	Conducted by Contractor QA, results must be within 25% of nominal
Technical System Audit	Facility visits, review of results	Throughout Study		To be determined	One event	Conducted by Contractor QA

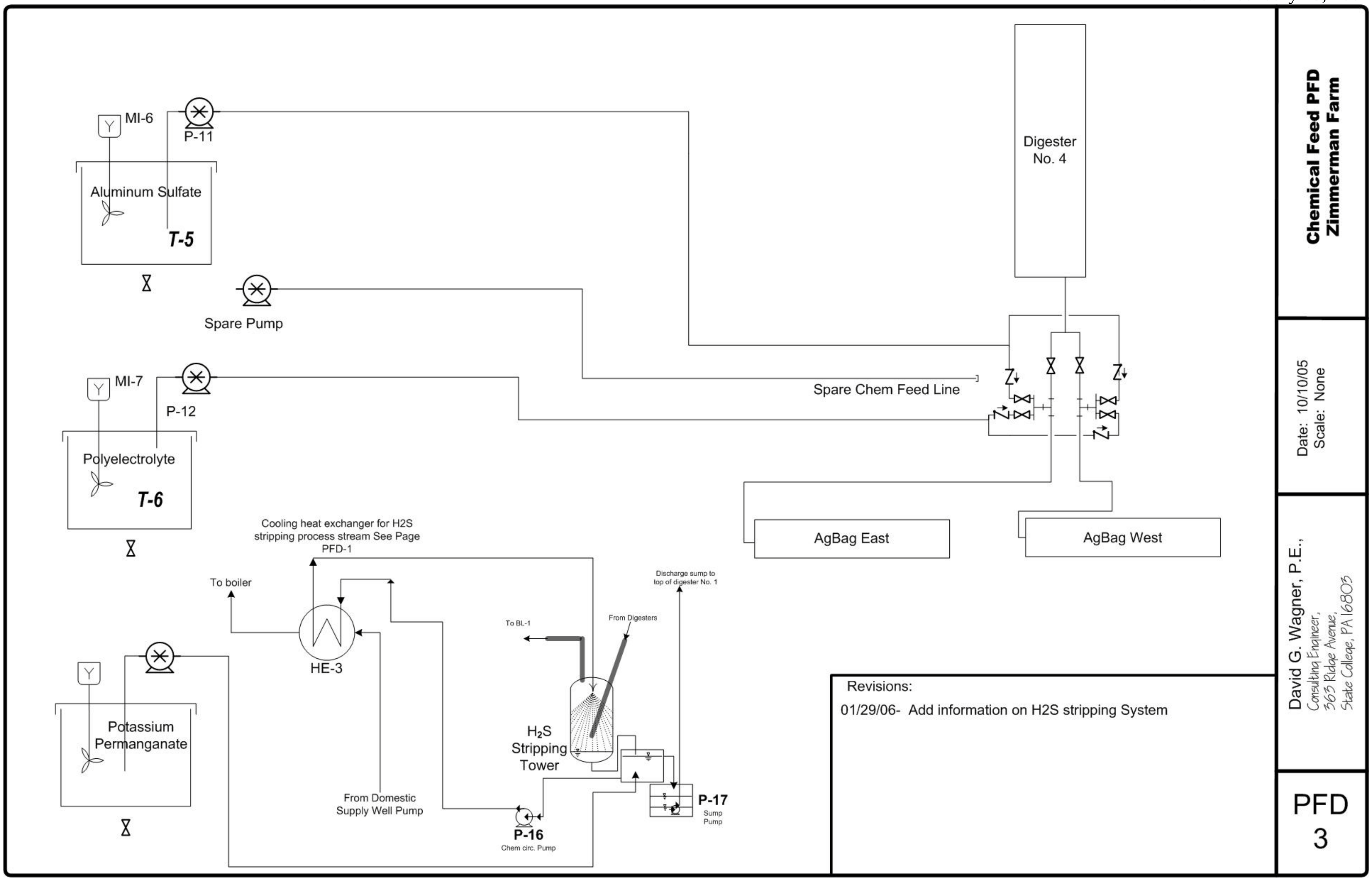
APPENDIX D

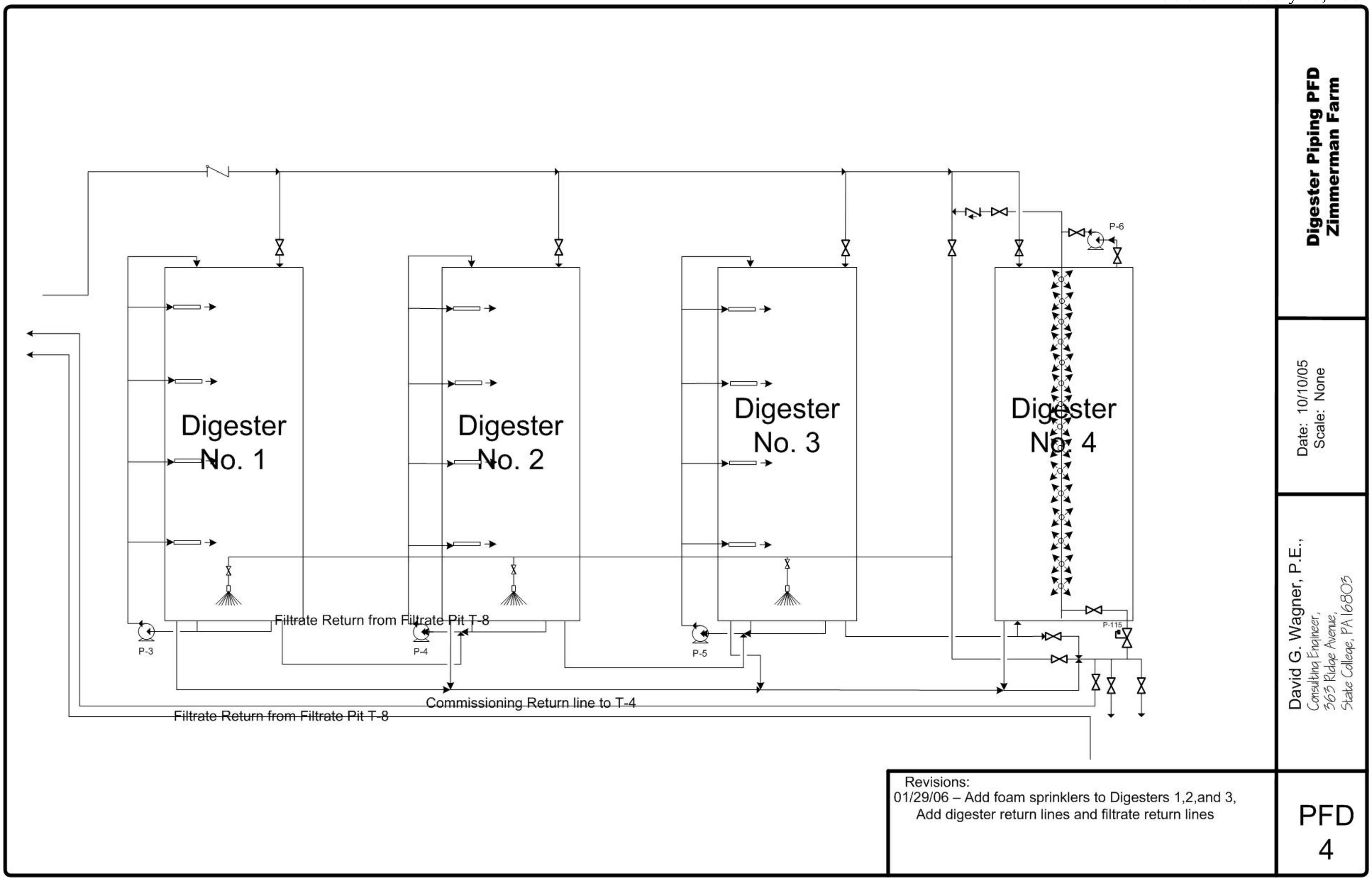
System Schematics

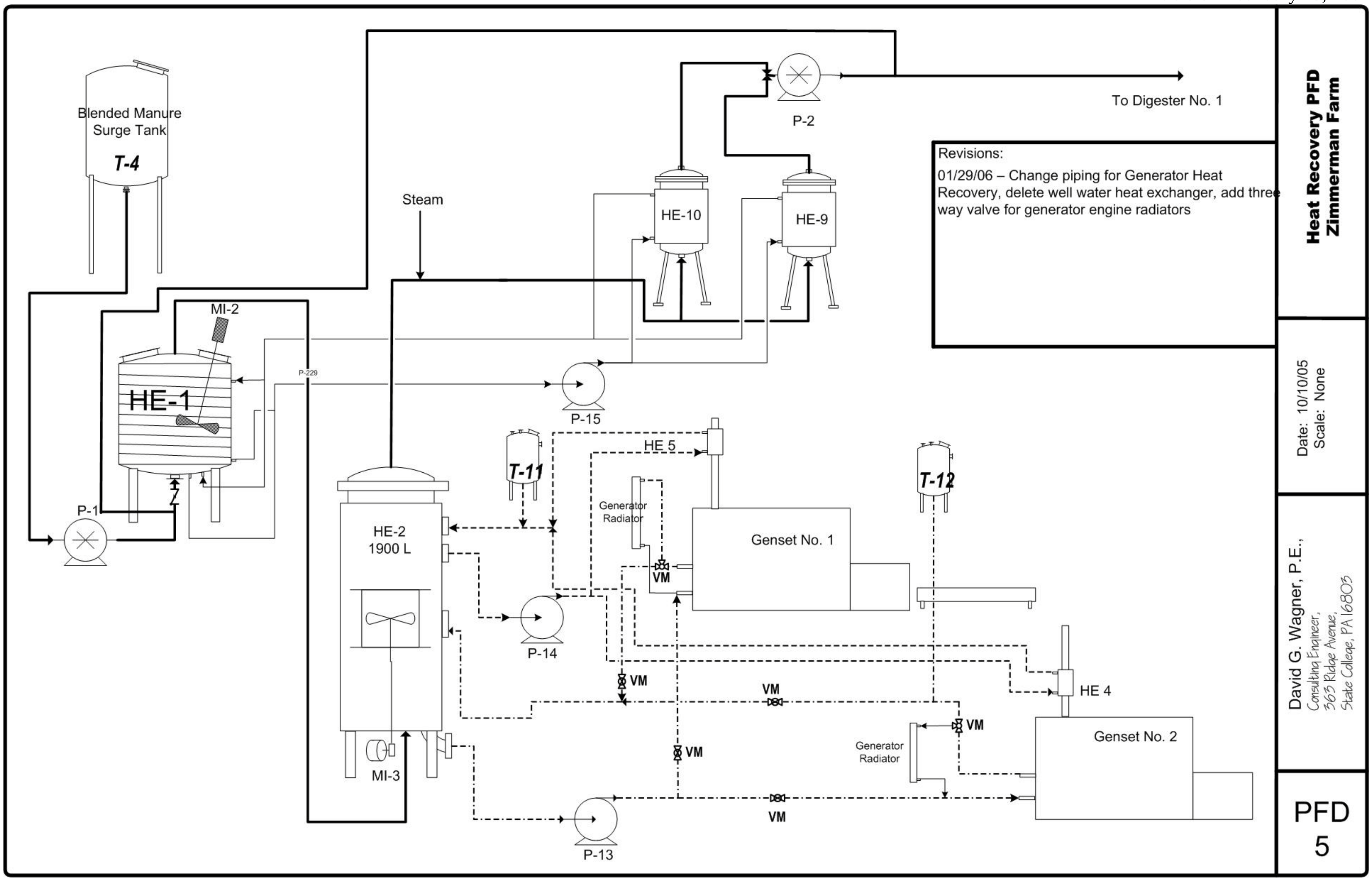
Provided by Wagner Anaerobics


Revisions: 01/29/06- Correct to Asbuilt Condition
Process Flow Diagram (PFD)
Zimmerman Farm
Date: 10/10/05
Scale: None
David G. Wagner, P.E.,
Consulting Engineer,
363 Ridge Avenue,
State College, PA 16803
PFD 1
Lower Gutter Scrape Building.
Loafing Yard
Skid Steer Scrape
Skidsteer Yard Scrape
Rainfall Runoff
Yard Runoff Storage Tank
T-1
P-9
T-2
MI-1
VA-1
P-10
VA-2
Slatted Barn
MI-4
P-8
T-3
Truck
Earl's Farm
Heat Recovery between HE-10/HE-9 and HE-1 not shown See Page PFD-5
MI-3
HE-2
HE -10
HE -9
P-2
MI-2
HE-1
P-15
P-1
T-4
Cooker Feed Tank
VA-3
VA-4
B-1
VA-5
HE-3
Bag Digester
Bag Digester
D-1
D-2
D-3
D-4
VA-6
VA-7
VA-8
P-3
P-4
P-5
P-6
VA-11
VA-10
T-8
P-7a
P-7b
VA-9
T-7
SlurryStore
Irrigation Pump Not Part of Contract
Biogas H2S stripping Tower not shown. See Page PFD 3 and PFD-7
MI-6
MI-7
T-5
T-6
P-12
P-11
BL-1
Chicken House # 1
Chicken House # 2
Chicken House # 3
Chicken House # 4
Skidsteer
Skidsteer
Skidsteer
Skidsteer
Skidsteer
Primary Chicken Manure Storage
Well Pump
Well and Pump Not part of Contrac
P-14
HE-4
P-13
VA-13
HE-5
VA-12
Gen Set 1
Gen Set 2
Generator Engine Cooling Water Heat Recover Piping Not completely shown. See Page PFD-6
Gas Storage
T-9
VM
Flare
F-17
VM
15/5 Raw Biogas
14/5 H2S Stripped Biogas
11/5 Raw Blended Manure
11/3 Digested Sludge
23/5 Filtrate
01/5 Demineralized Well Water
20/3 Steam
02/5 Heat Treated Manure


T-4
Cooker Feed Tank
T-10 Not Used
Manure Final Heating Stage Tank
D-1
D-2
D-3
D-4
P-20
P-21
Digester No. 1
Digester No. 2
Digester No. 3
Digester No. 4
Slatted Barn
Blending Pit
T-3
VA-4
VA-5
VA-6
VA-7
VA-8
Valves VA-4, VA-5, VA-6, VA-7, and VA-8 are 110 volt solenoid steam control valves.
Boiler
B-1
VA-3 is Boiler Blowoff Automatic Valve
VA-3
Cooling heat exchanger for H2S stripping process stream See Page PFD-7
HE-3
Well Pump
Well Pump
Well and Well Pump not part of contract
WELL
P-17
Feedwater Pump part of Boiler Control Package
Boiler Feedwater Pump and Condensate Tank
Boiler Feedwater Pump
Revisions:
01/29/06 – T-10 Not Used, HE-3 Add Note
Steam Piping PFD
Zimmerman Farm
Date: 10/10/05
Scale: None
David G. Wagner, P.E.,
Consulting Engineer,
363 Ridge Avenue,
State College, PA 16803
PFD
2


MI-6
P-11
Aluminum Sulfate
T-5
Spare Pump
MI-7
P-12
Polyelectrolyte
T-6
Potassium Permanganate
Digester No. 4
Spare Chem Feed Line
AgBag East
AgBag West
Cooling heat exchanger for H2S stripping process stream See Page PFD-1
To boiler
HE-3
From Domestic Supply Well Pump
To BL-1
From Digesters
Discharge sump to top of digester No. 1
H2S Stripping Tower
P-16
Chem circ. Pump
P-17
Sump Pump
Revisions:
01/29/06- Add information on H2S stripping System
Chemical Feed PFD
Zimmerman Farm
Date: 10/10/05
Scale: None
David G. Wagner, P.E.,
Consulting Engineer,
363 Ridge Avenue,
State College, PA 16803
PFD
3


Digester No. 1
Digester No. 2
Digester No. 3
Digester No. 4
P-3
P-4
P-5
P-6
P-115
Filtrate Return from Filtrate Pit T-8
Commissioning Return line to T-4
Filtrate Return from Filtrate Pit T-8
Revisions:
01/29/06 – Add foam sprinklers to Digesters 1,2,and 3,
Add digester return lines and filtrate return lines
Digester Piping PFD
Zimmerman Farm
Date: 10/10/05
Scale: None
David G. Wagner, P.E.,
Consulting Engineer,
363 Ridge Avenue,
State College, PA 16803
PFD
4


Blended Manure Surge Tank
T-4
MI-2
HE-1
P-229
P-1
Steam
HE-2
1900 L
MI-3
HE-10
HE-9
P-2
To Digester No. 1
P-15
P-14
P-13
T-11
T-12
HE 5
HE 4
Generator Radiator
Generator Radiator
Genset No. 1
Genset No. 2
VM
VM
VM
VM
VM
VM
Revisions:
01/29/06 – Change piping for Generator Heat Recovery, delete well water heat exchanger, add three way valve for generator engine radiators
Heat Recovery PFD
Zimmerman Farm
Date: 10/10/05
Scale: None
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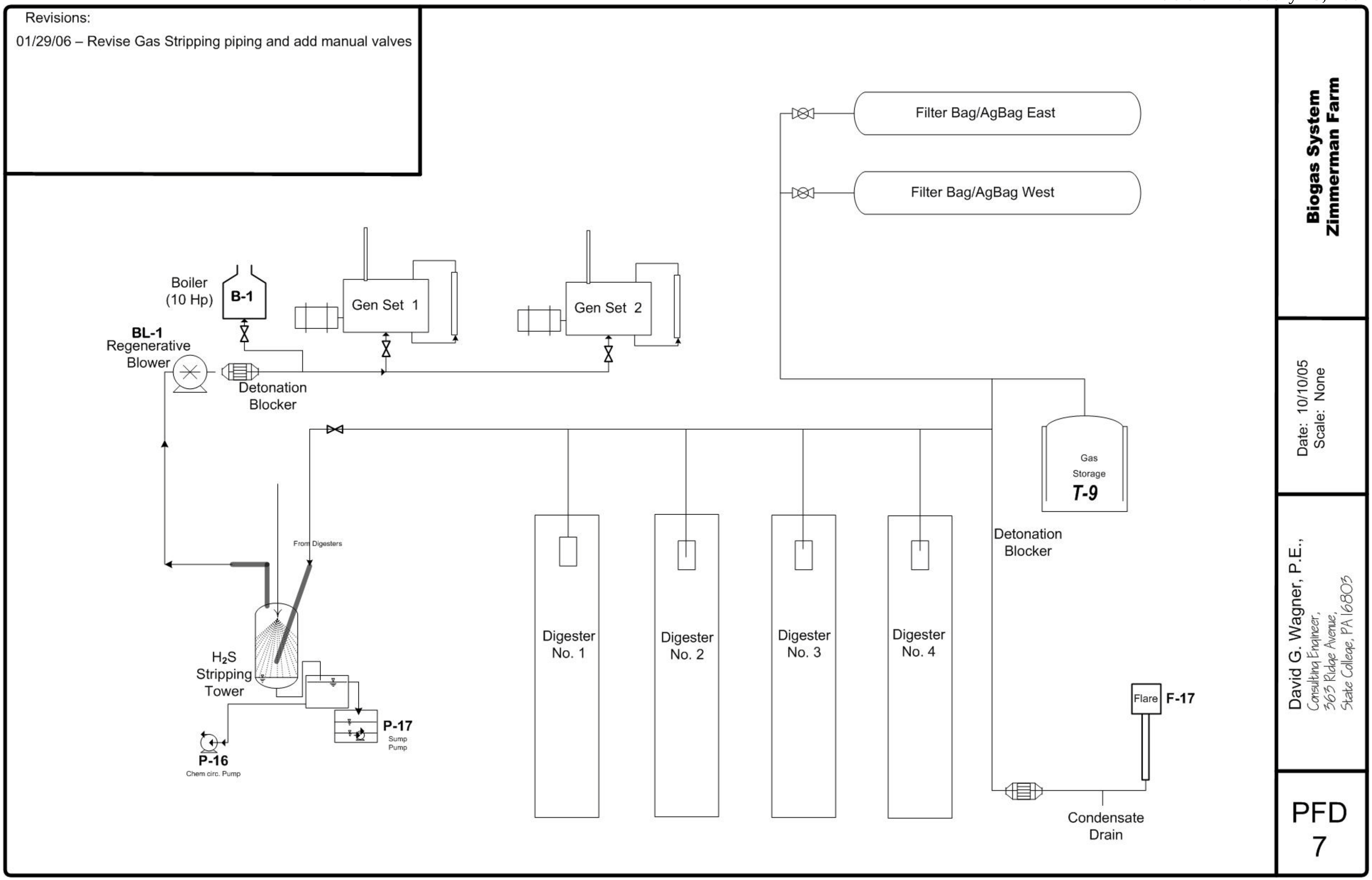
363 Ridge Avenue,
State College, PA 16803
PFD
5


Revisions:
01/29/06 – Revise Gas Stripping piping and add manual valves
Filter Bag/AgBag East
Filter Bag/AgBag West
Boiler
(10 Hp)
B-1
Gen Set 1
Gen Set 2
BL-1
Regenerative
Blower
Detonation
Blocker
Gas
Storage
T-9
From Digesters
H2S
Stripping
Tower
P-17
Sump
Pump
P-16
Chem circ. Pump
Digester
No. 1
Digester
No. 2
Digester
No. 3
Digester
No. 4
Detonation
Blocker
Flare
F-17
Condensate
Drain
Biogas System
Zimmerman Farm
Date: 10/10/05
Scale: None
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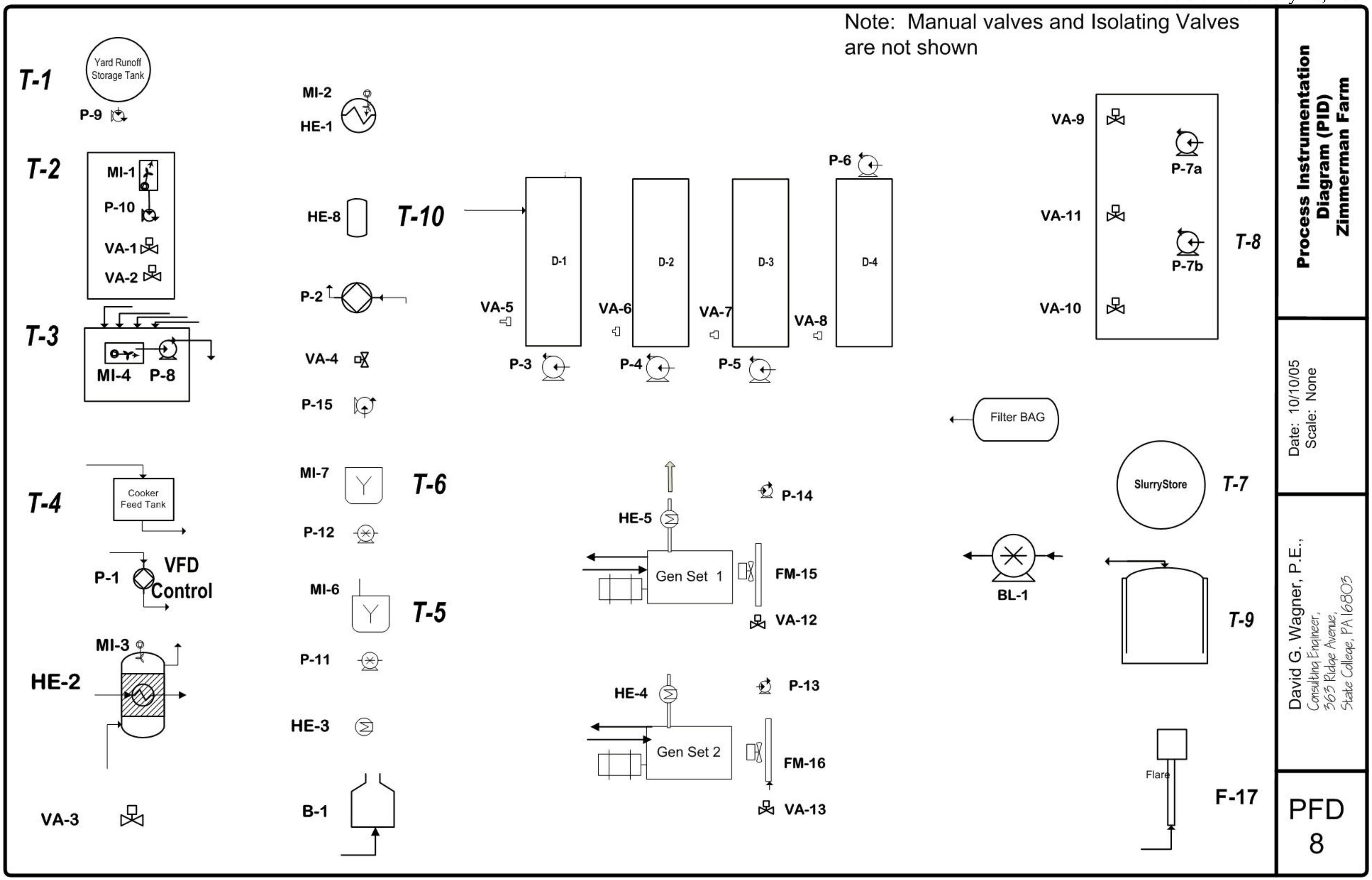
7


Note: Manual valves and Isolating Valves are not shown
T-1
Yard Runoff Storage Tank
P-9
T-2
MI-1
P-10
VA-1
VA-2
T-3
MI-4
P-8
T-4
Cooker Feed Tank
P-1
VFD Control
MI-3
HE-2
VA-3
MI-2
HE-1
HE-8
T-10
P-2
VA-4
P-15
MI-7
T-6
P-12
MI-6
T-5
P-11
HE-3
B-1
D-1
D-2
D-3
D-4
VA-5
VA-6
VA-7
VA-8
P-3
P-4
P-5
P-6
HE-5
Gen Set 1
P-14
FM-15
VA-12
HE-4
Gen Set 2
P-13
FM-16
VA-13
VA-9
P-7a
VA-11
P-7b
VA-10
T-8
Filter BAG
BL-1
SlurryStore
T-7
T-9
Flare
F-17
Process Instrumentation Diagram (PID) Zimmerman Farm
Date: 10/10/05
Scale: None
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Consulting Engineer,
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PFD
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APPENDIX E

TEST/QA PLAN ADDENDUM

Environmental Technology Verification Program

Environmental and Sustainable Technology Evaluations

Test/QA Plan for Verification of Anaerobic Digester for Energy Production and Pollution Prevention

TEST/QA PLAN

REVISED ADDENDUM

April 14, 2008

This revised addendum of the Test/QA Plan for the Verification of Anaerobic Digester for Energy Production and Pollution Prevention was prepared by Eastern Research Group, Inc. (ERG) under EPA contract EP-C-05-059. This addendum documents the revisions to the test plan/QAPP document that are realized at implementing verification testing.

Verification Test Objectives

The following testing objectives will be implemented for the ESTE-ETV Anaerobic Digester Verification program.

Air Quality

1. Quantify the reductions realized in methane and fossil fuel derived carbon dioxide emissions. (The reduction in methane emissions is likely to be somewhat minimal due to the existing method of manure storage.)
2. Assess the reduction in noxious odor emissions on subjective basis.

Water Quality

1. Quantify the reduction oxygen demanding organic compounds realized through reduction to methane and carbon dioxide.
2. Quantify the reduction in the potential for pathogen transport to adjacent surface waters based on reductions in indicator organism densities.
3. Characterize the transformations in nitrogen and phosphorus to assess the reduction or increase in potential impacts.
4. Delete the dewatering/phosphorus concentration aspect of the project.

Testing Approach

1. Influent Composition. Influent composition will depend on the availability of beef cattle manure during the 12-month period of the performance evaluation. If an adequate supply of beef cattle manure will not be available consistently throughout the period of the performance evaluation, the beef cattle manure that will be available will be supplemented with broiler manure to maintain the desired volumetric loading rate. To maintain a constant organic loading rate, the ratio, on a volumetric basis, of beef cattle manure to broiler manure will be held constant. Only the caked broiler manure removed after each flock will be used.

2. Operating Parameters. The system will be considered ready for evaluation under steady-state conditions when operation for a period equal to five hydraulic retention times at the influent flow rate of 6.5 gal per minute (~33 days) with constant rates of biogas and methane production. Methane production shall be at least 55 percent of biogas production. The composition of the influent that will be used during the establishment of steady-state conditions and the period of the performance evaluation shall be the same.

   - Temperature. The temperature of the first reactor will be held constant at 55 °C and the temperature of the remaining three reactors will be held constant at 35 °C beginning with the period of operation to establish steady-state conditions.

   - HRT. The influent flow rate will be held constant at 6.5 gal per minute, which will provide a hydraulic retention time of approximately 6.6 days.

Sampling, Data Collection and Laboratory Analysis

1. Physical, Chemical, and Microbial Transformations. Monthly samples of the influent and the effluent from the pretreatment process and of the influent to and effluent from the anaerobic digestion system. These samples will be analyzed for the following: total solids, total volatile solids, chemical oxygen demand, total volatile acids, total Kjeldahl nitrogen, ammonia nitrogen, total phosphorus, total soluble phosphorus concentrations; pH; *E. coli*, fecal coliform and fecal streptococcus densities; and temperature.

2. Biogas Production and Utilization. Monthly values will be determined for total biogas production, biogas utilization to generate electricity; biogas utilization, if any, to generate heat directly; and excess biogas disposal via flaring. Accepting the developer's statement that flaring will not be needed for disposition of gas (emergency release only), two gas meters (Actaris 1000A-TC meters) will be installed for measuring total biogas production and measuring biogas production used for generating electricity for on-farm use and delivery to the grid.

3. Electricity Production and Utilization. Monthly measurements will be completed to determine kWh generation; parasitic demand (electric and thermal); KWh utilized on-site and delivered to the grid.

A summary of the laboratory analytical testing requirements is provided in the following table.

Anaerobic Digester ETV - Revised Analytical Testing Requirements

Parameter	Method	Sampling Frequency	Sample Type	Samples Analyzed per Event	Total Sampling Events	Total Samples	Lab
Total Solids	EPA 160.3	Monthly	Influent and effluent composites	4	12	48	Midwest
TVS	EPA 160.4	Monthly	Influent and effluent composites	4	12	48	Midwest
TVA	STM(2005) 5560C (total volatile acids)	Monthly	Influent and effluent composites	4	12	48	Midwest
Fixed Solids	Determined by difference of TS and TVS	Monthly	From AVG of TS and TVS results	4	12	48	Midwest (calculated)
COD	EPA 410.4	Monthly	Influent and effluent composites	4	12	48	Midwest
NH3-Nitrogen	EPA 350.1	Monthly	Influent, filtrate and effluent composites	4	12	48	Midwest
Total Kjeldahl Nitrogen	EPA 351.2	Monthly	Influent, filtrate and effluent composites	4	12	48	Midwest
Total Organic Nitrogen	Determined by difference of NH3-N and TKN	Monthly	From AVG of TKN and NH3 results	4	12	48	Midwest (calculated)
Total Phosphorus	EPA 365.4	Monthly	Influent, filtrate and effluent composites	6	12	48	Midwest
Dissolved Ortho Phosphate	EPA 365.3	Monthly	Influent, filtrate and effluent composites	6	12	48	Midwest

Parameter	Method	Sampling Frequency	Sample Type	Samples Analyzed per Event	Total Sampling Events	Total Samples	Lab
E. Coli	STM(2002) Multiple Tube 9223B 15 tube MPN	Monthly	Influent and effluent composites	4	12	48	Midwest
Total/ Fecal Coliforms	STM(2002) Multiple Tube 9221A-C 15 tube MPN	Monthly	Influent and effluent composites	4	12	48	Midwest
Total/Fecal Strep.	STM(2002) Multiple 9230A-B 15 tube MPN	Monthly	Influent and effluent composites	4	12	48	Midwest
Salmonella	STM(2002) Multiple Tube 9260D MPN	Monthly	Influent and effluent composites	4	12	48	Midwest
pH	EPA 150.1	Monthly	Influent, filtrate and effluent composites	3	12	36	Midwest
NPK rations plus total carbon	Penn State Ag. Lab Standard Manure Test 1	Quarterly	Solids composite	1	4	4	Shaw
Gas Composition	CH4 and CO2 ASTM D1945	Quarterly	From gas flow meter	3	4	12	Midwest
Manure Biodegradability	Shaw Laboratory SOP	One time	Raw and cooked manure and digester influent	3	1	3	Shaw